Gas Clean-up and Conditioning

DOE OBP Thermochemical Platform Review Meeting
June 7-8, 2005

Richard Bain, NREL

Presentation Outline

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- **Session Agenda**
- **Strategic Fit of Projects in Session**
  - **TC Area fit**
  - **Stage gate fit**
  - **Pathways fit**
  - **Milestone fit**
- **Technical Barriers Addressed**
- **Customers**
- **Legal/Regulatory Compliance**
- **Session Project Budgets**

Session Agenda

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Session 1: WBS 3.3 Clean-up and Conditioning Chair: Richard Bain (NREL)	
7:50	Overview – R. Bain, NREL
8:10	Integrated Catalyst Studies – D. Dayton, NREL
8:40	Catalyst Fundamentals - K. Magrini, NREL
9:10	Verification of Syngas Quality – J. White, PNNL
9:40	Sulfur Removal and Gasification Membranes – R. Bain, NREL
10:10	Break
10:40	Syngas Clean-up using a Therminator– S. Gangwal, Research Triangle Inst.
11:00	Catalysts for In-Process Elimination of Tars – L. Felix, Gas Technology Inst.
11:20	Trace Metal Scavenging from Syngas – T. Gale, Southern Research Inst.

Thermochemical Platform

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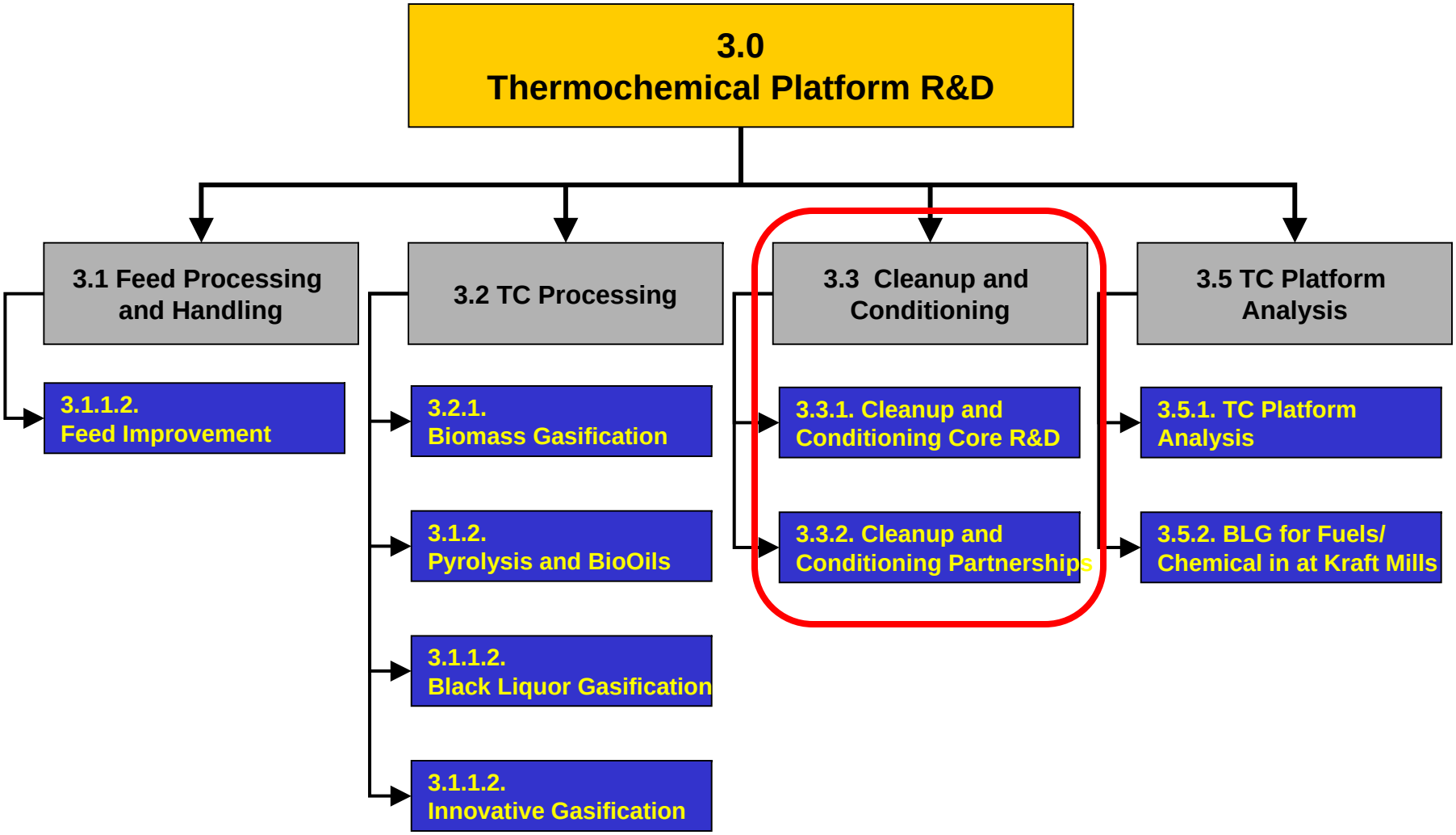

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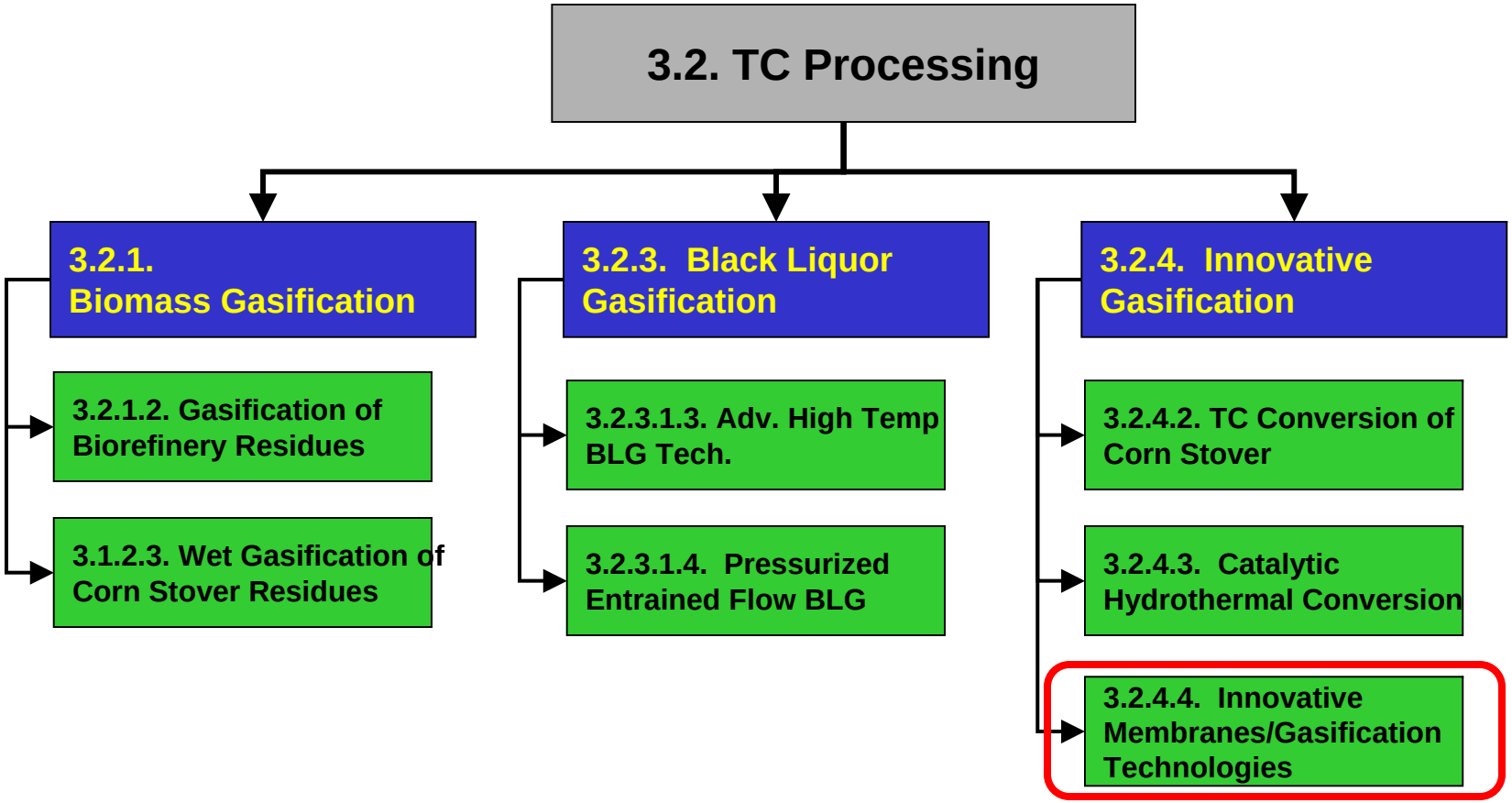

3.5.1. TC Platform Analysis

3.5.2. Gasification for Fuels/ Chemicals in a Kraft Mill

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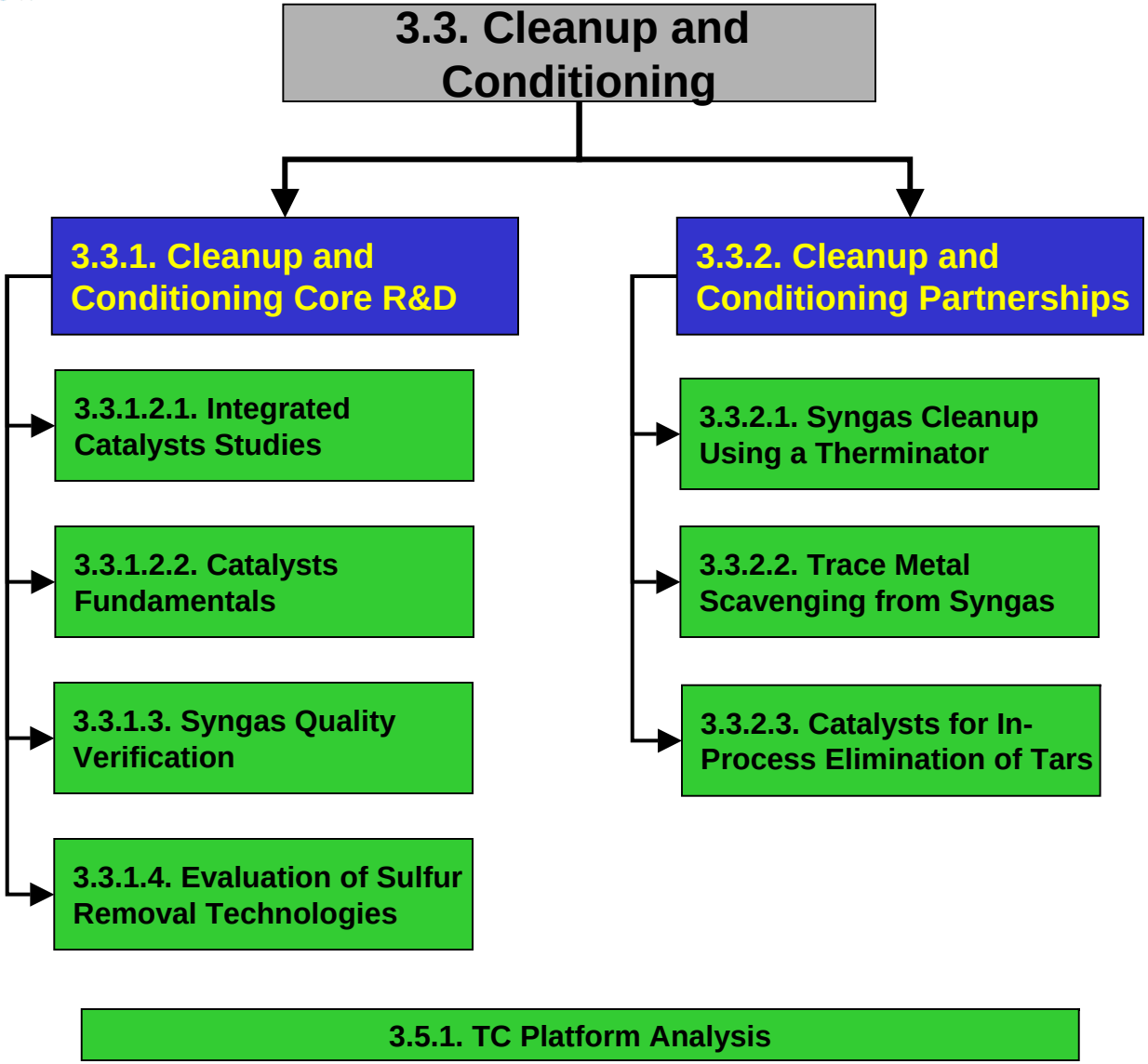
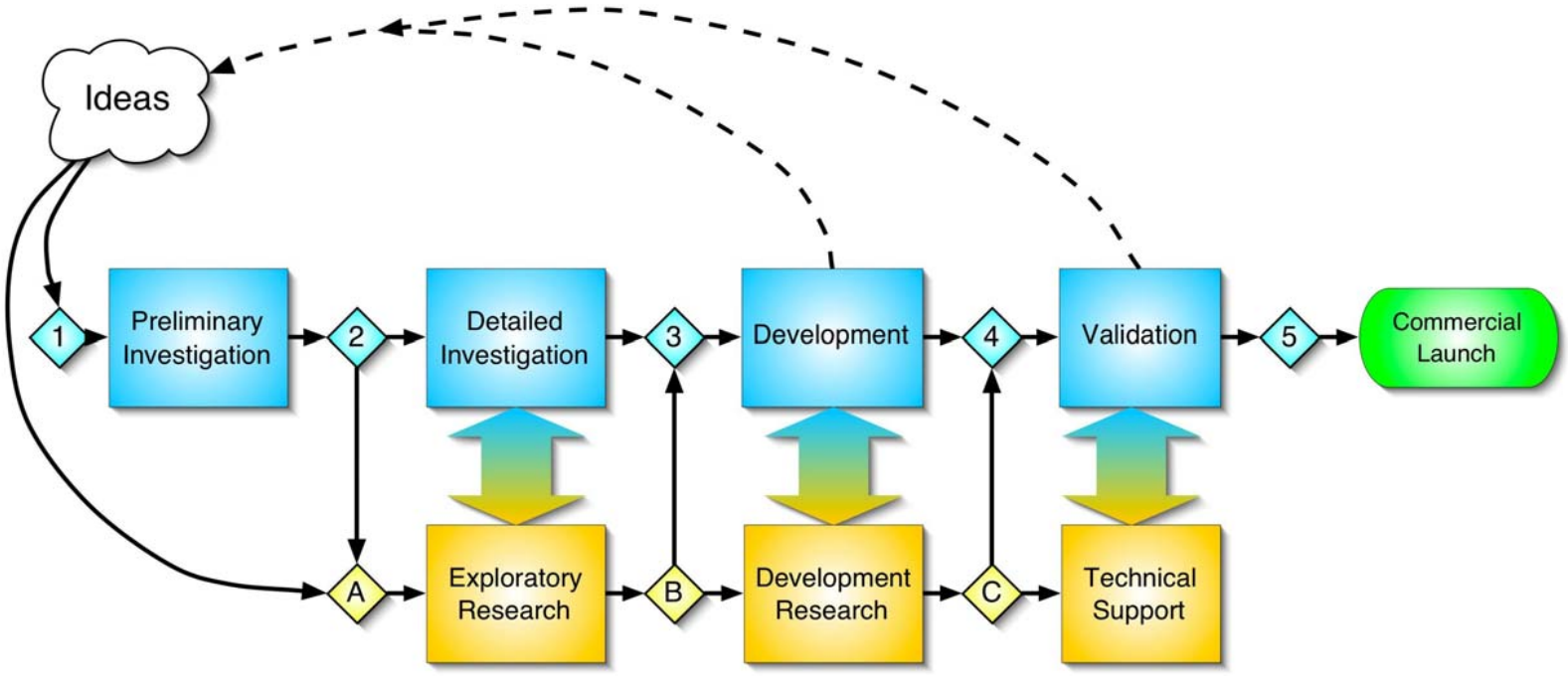


What Stage is the project in?



Stage Gate Fit

Project	Stage
Integrated Catalyst Studies (NREL)	RT Stage B, Development Research
Catalyst Fundamentals Studies (NREL)	RT Stage B, Development Research
Verification of Syngas Quality (PNNL/NREL)	RT Stage A, Exploratory Research
Sulfur Removal and Gasification Membranes (NREL/PNNL)	RT Stage A, Exploratory Research
Syngas Cleanup Using a Therminator (RTI)	RT Stage B, Development Research
Trace Metal Scavenging from Syngas (SRI)	RT Stage B, Development Research
Catalysts for In-Processing Removal of Tars (GTI)	RT Stage B, Development Research

CT = Commercial Track
RT = Research Track

Technical Barrier Areas

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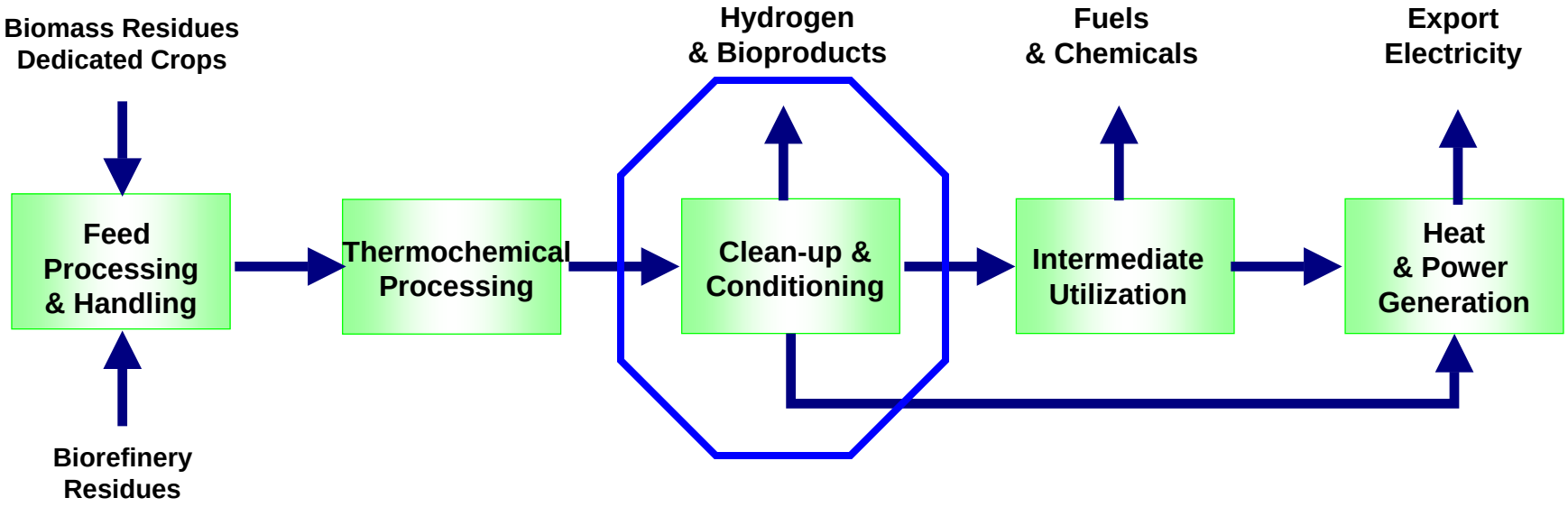

Objectives/Tech Feasibility/Competitive Advantage:

- **Produce Clean Syngas Meeting Downstream Cleanliness Requirements**
  - **Tars {e.g. <0.1 mg/Nm^3 for methanol synthesis}**
  - **Heteroatoms {e.g. <0.1 mg/Nm^3 for methanol synthesis}**
  - **Inorganics {e.g. < 0.01 mg/Nm^3 for methanol synthesis}**

    Source: "Unit Operations of Biomass Gasification," Report 2DEN-02.20, NOVEM, 2002
- **Reduce Light Hydrocarbons – impact in overall process costs**
- **Reduce carbon emissions, versus fossil-based processes**

Technical Barriers Addressed

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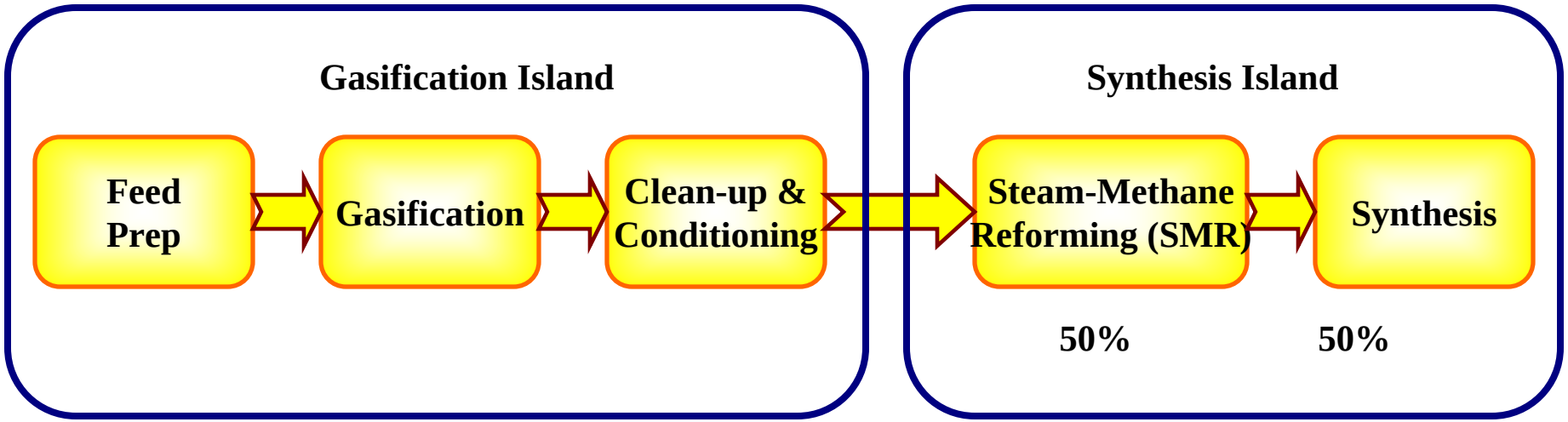
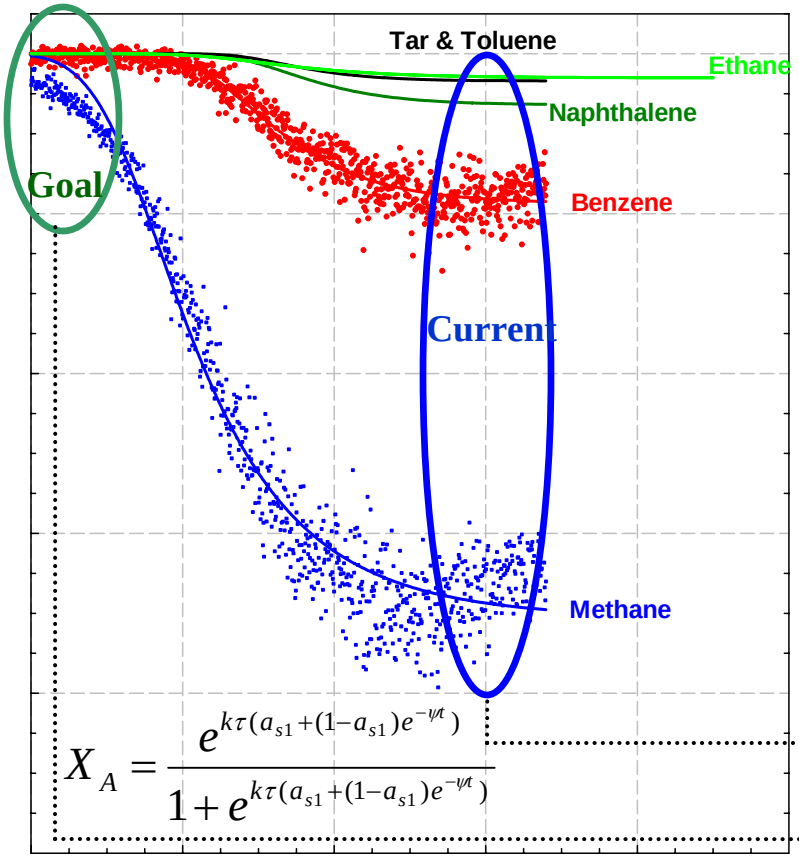


60% of Cost **40% of Cost**

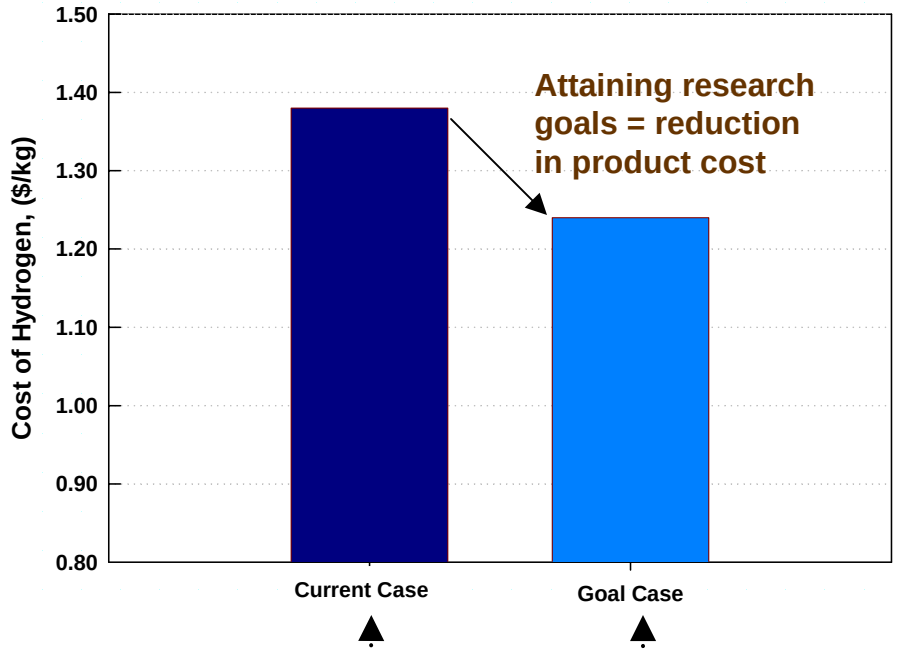
Reforming of light hydrocarbons in conditioning step can eliminate the need for SMR, potentially saving 20% in capital

Catalytic Cleanup – Current & Goal Conversions

Results from NREL's PDU tar reformer



Potential Impact of Reformer Eficiency of Cost of Hydrogen (2,000 TPD Plant, Low-Pressure Steam Gasification)



Cost of SynGas

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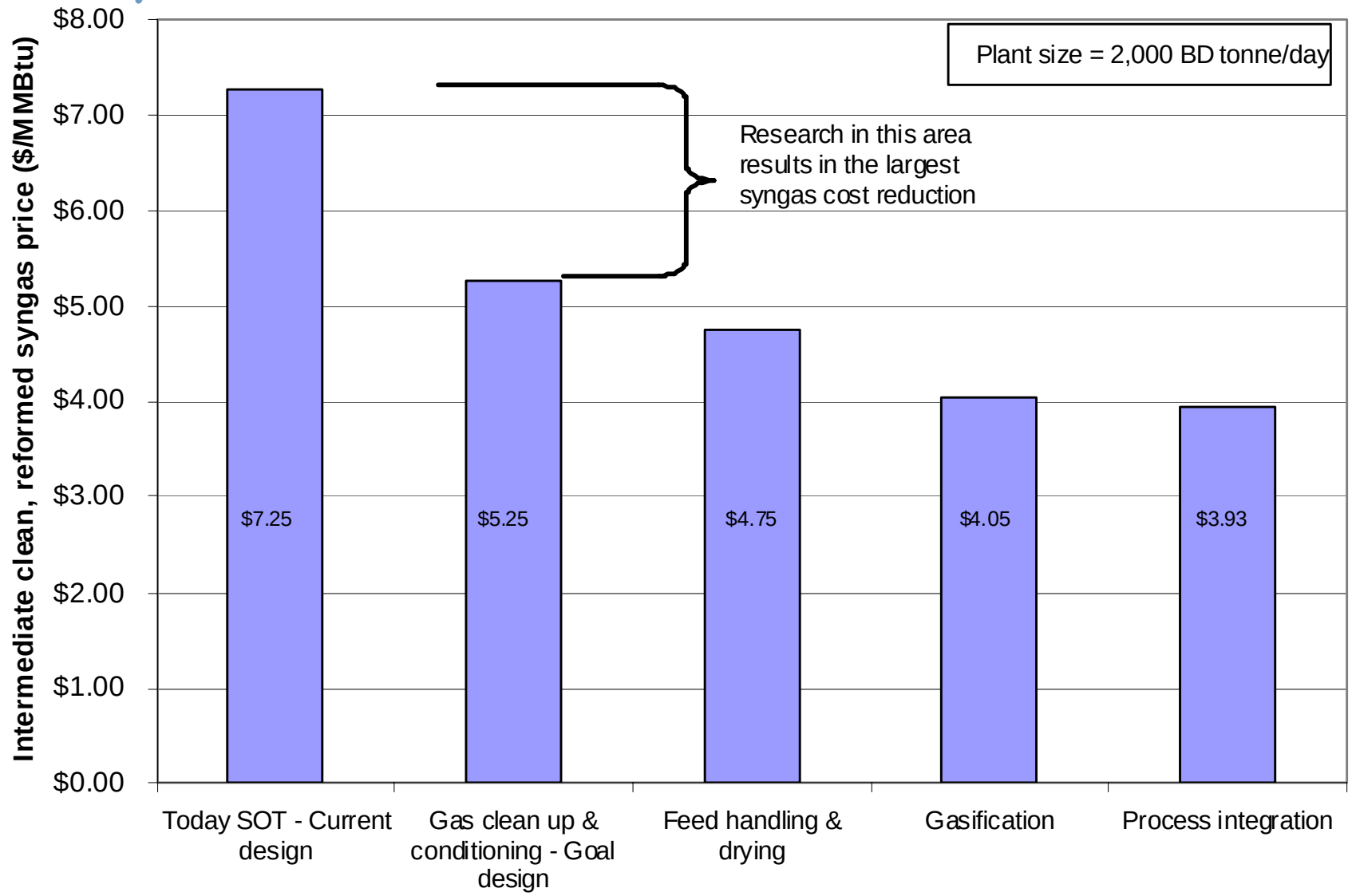

Pathways

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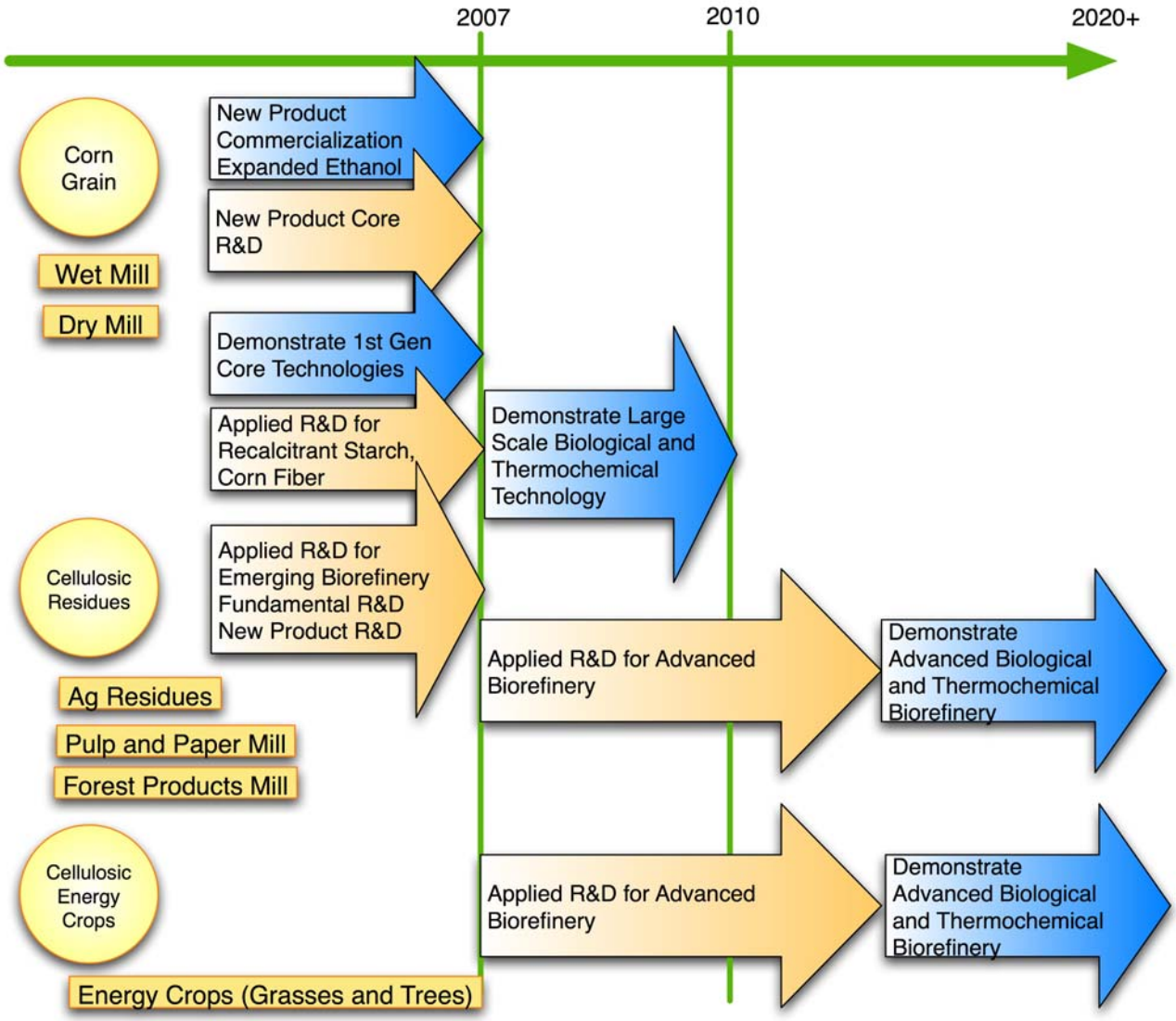

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Pathways and Milestones – A & B Level Milestones

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A-level Milestones
Systems Level Demonstrations

Complete systems level demonstration and validation of all key technologies to utilize ***Agricultural residues feedstocks and perennial crops*** in existing or new facilities

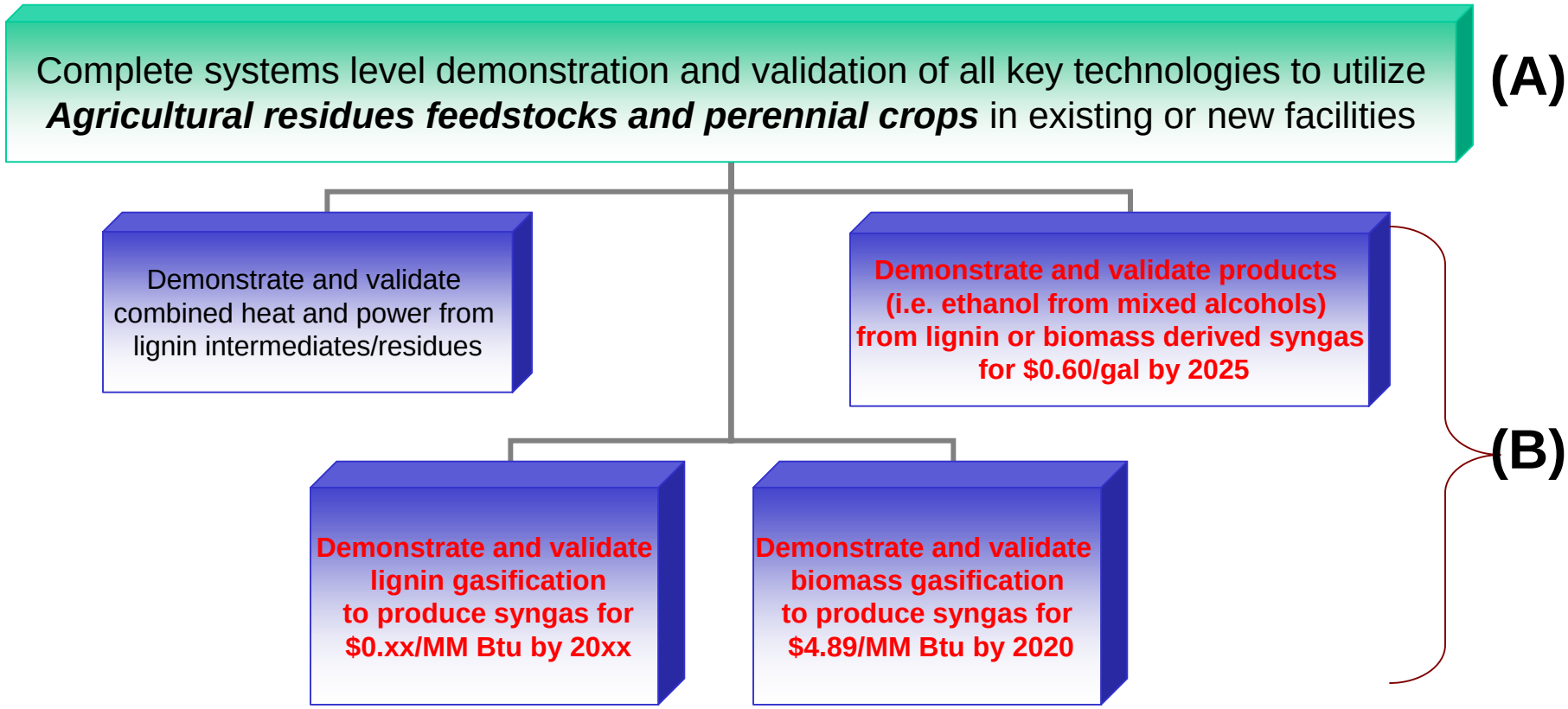
- Demonstrate and validate combined heat and power from lignin intermediates/residues
- **Demonstrate and validate products (i.e. ethanol from mixed alcohols) from lignin or biomass derived syngas for $0.60/gal by 2025**
- **Demonstrate and validate lignin gasification to produce syngas for $0.xx/MM Btu by 20xx**
- **Demonstrate and validate biomass gasification to produce syngas for $4.89/MM Btu by 2020**

Complete systems level demonstration and validation of technologies to improve pulp and paper mill facilities and/or produce additional products (fuels, chemicals and /or power) from wood feedstock in ***pulp and paper and forest product mills*** environment

- Demonstrate and validate reliable and economic gasification of spent pulping liquor and recycle liquor causticization in a pulp mill
- Demonstrate and validate syngas utilization in a pulp or forest products mill including clean cold gas
- **Demonstrate and validate cost-effective biomass gasification of wood residues and other process residues and synthesis gas cleanup in a pulp and paper or forest products mill environment**
- **Demonstrate and validate production of DME/mixed alcohols/FT liquids or other products from syngas in a pulp or forest products mill at a price competitive with current commercial practice**
- Demonstrate and validate bio-oil production to a stable intermediate
- Demonstrate and validate gas cleanup and process chemical recovery and recycle from spent pulping liquor syngas
- Achieve cost-effective conversion of bio-oil intermediate into product(s) in a forest products mill

B-level Milestones
Cost Targets

Relationship of Milestones to Pathways



Impact of Thermochemical Platform R&D on A and B Milestones in the Pulp and Paper and Forest Products Pathway

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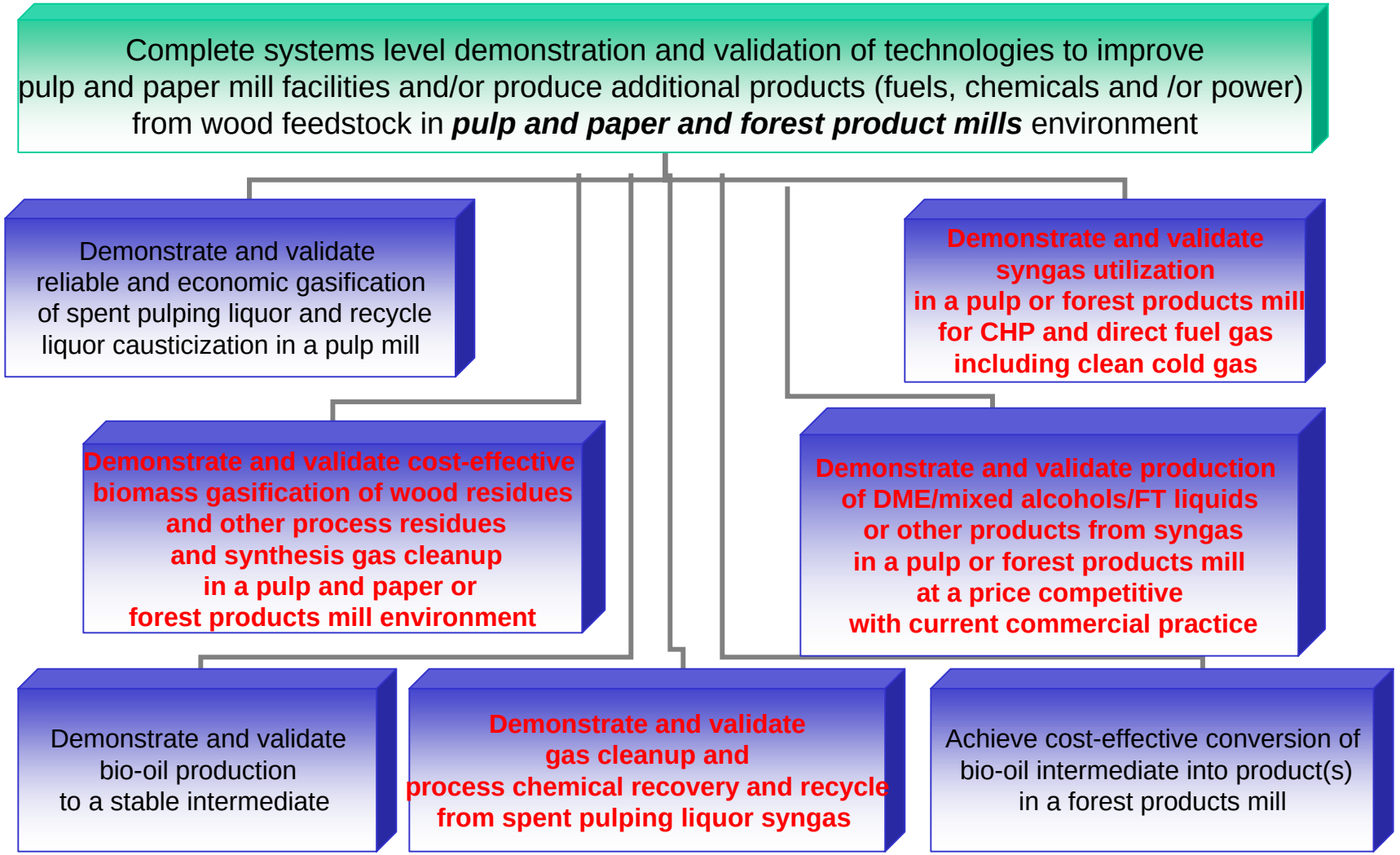
Relationship of Milestones to Pathways



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Pathways and Milestones – C-level and Project Milestones

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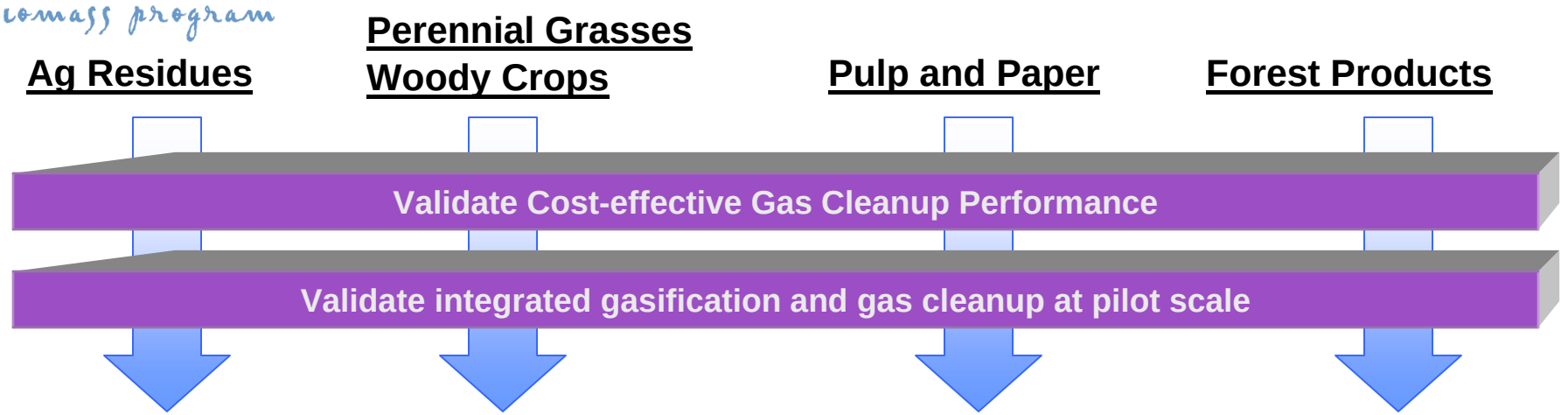

Project Milestones	Type	Performance Expectations	Due Date

Customers

- Customers are the current and future operators of biomass processing facilities, and the partners who provide them with engineering and equipment.

Legal/Regulatory Compliance

- There are regulatory drivers that may support TC technology (cluster rules and VOC emissions)
- There are no specific, individual patents that are required for the commercialization. There are a number of alternative patents for gas clean-up and product synthesis.

Other

- The operational conditions, systems integration and size of the technology will vary with the different for the different pathways, e.g., current dry mills, pulp and paper (BLG) compared to and future integrated BC/TC biorefineries
- There are numerous examples of commercial technology for the conversion of syngas to fuels and chemicals

Project Budgets

Project	FY 04	FY 05	FY 06 Plan	Future Plan
3.1 Feed Processing & Handling		400	300	
3.2. Gasification	2,725	1,667	1,220	
3.3 Cleanup and Conditioning	**3,053**	**4,273**	**3,470**	
3.5 TC Analysis	851	750	610	
Total Funding	6,629	7,090	5,600	